Productivity in industrial inorganic chemicals

Output per hour improvements were retarded by slack demand; economies of scale could not be fully exploited, but cutbacks of less efficient plants, together with technical advances, bolstered productivity levels

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As measured by output per hour, productivity in the inorganic chemicals industry remained virtually unchanged between 1972 and 1986.[1] By comparison, output per hour in manufacturing, as a whole, rose at an average annual rate of 2.7 percent over the period. Neither output of the industry nor employee hours changed significantly over the 1972–86 timespan—the long-term trends were essentially flat.

The absence of any long-term improvement in productivity did not characterize all of the industry's components. In the manufacture of alkalis (mostly caustic soda) and chlorine, productivity rose 3.2 percent a year, reflecting a decline in output and an even greater decline in employee hours. In the manufacture of inorganic pigments, productivity improved at an 0.9-percent annual rate; here, too, the long-term gain resulted from receding output and hours. In the largest group of inorganic chemicals—including most basic or commodity and large numbers of miscellaneous chemicals—productivity declined slightly, by 0.2 percent a year. Here, output rose, as did employee hours, if at a somewhat higher rate than output.

The inorganic chemicals industry converts certain nonfuel minerals and gaseous fluids found in the atmosphere into specifically formulated mixtures, generally used as intermediates in the production of final goods. One characteristic, particularly of large plants, is continuous processing, and relatively "very little direct labor (is) used" in the industry.[3] Value added per production worker has been roughly twice that for all manufacturing, and the ratio of fixed assets to employment has been 3 to 4 times as high, bespeaking the capital intensity of the industry.[4]

The longer term trend in the industry's productivity exhibited two phases. Between 1972 and 1979, productivity grew at an average annual rate of 1.2 percent, with output rising at a rate $2\frac{1}{2}$ times that of employee hours. Capacity utilization rose, hitting a high of 84 percent in 1979. However, from 1979 to 1986, productivity, although marked by sharp year-to-year swings, slowed to 0.9 percent a year with both output and employee hours falling slightly. Capacity utilization receded to as low as 62 percent.[5]

The following tabulation indicates the productivity trend and its phases for the industry as a whole and for its components (see also tables 1 to 4):

	Average annual rates (percent)		
	1972–86	1972–79	1979–86
Inorganic chemicals	0.3	1.2	0.9
Alkalies and chlorine ..	3.2	.4	7.8
Inorganic pigments	.9	−1.7	4.4
Other basic and miscellaneous inorganic chemicals	−.2	2.0	−1.8
All manufacturing	2.7	1.9	3.5

NOTE: In this and the following tabulations, inorganic chemicals exclude government-owned plants and include industrial gases, not shown separately. "Other" inorganic chemicals is a category "not elsewhere classified" by the Bureau of the Census.

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As the tabulation suggests, the productivity performance of the industry was dominated by the "other basic and miscellaneous inorganic chemicals" group, which accounted for two-thirds of total industry employment. During the 1972–79 period, the comparatively weak showing of the alkalies and chlorine and of the industrial pigments industries contrasted with the improvement in that larger group; the reverse occurred during the subsequent timespan.

Year-to-year swings in output per hour in the industry ranged widely, between a drop of 17 percent (in 1972) and a spurt of nearly 13 percent in 1984. Year-to-year losses in productivity were related to output declines accompanied by lesser declines, or even increases, in hours. This pattern was especially marked by the "other basic and miscellaneous inorganic chemicals" group, whose volatility exceeded the overall industry average. Here, year-to-year movements ranged from a drop of 21 percent (in 1980) to a gain of 12 percent (in 1984).

In 1986, the industry's productivity ran 12 percent above 1972, but had not regained the peak of 112.2 attained in 1979. The "other" group's productivity still ran 12 percent below its 1979 high. By contrast, output per hour in inorganic pigments had climbed 16 percent above its previous high in 1974; in alkalies and chlorine, the 1986 productivity level had soared 56 percent above the earlier (1980) peak.

Demand and output

Inorganic chemicals "embrace all substances, except hydrocarbons and their derivatives" (that is, petroleum, coal, and natural gas.) Petroleum and natural gas are the fundamental feedstocks of organic chemicals and of such products as plastics. Inorganic chemicals often enter as intermediates in the production of organic chemicals.[6] The inorganic chemicals industry generally obtains its raw materials from minerals other than fuels, and from fluids (including the atmosphere and its gases). Together with many organic chemicals, inorganic chemicals are used throughout manufacturing as intermediates, the total value of their intermediate use being exceeded only by petroleum and natural gas, and petroleum refining.[7] The end uses of the more important inorganic chemicals are listed in exhibit 1.

Between 1972 and 1986, there was little change in output of inorganic chemicals, but its long-term trend, like that of productivity, displayed two distinct patterns. Between 1972 and 1979, output rose at an average annual rate of 2 percent; thereafter it declined by 0.3 percent a year, reflecting the cyclical downswing of the early 1980's. Toward the mid-1980's, output recovered but did not reach the high levels of the late 1970's. The "other basic and miscellaneous inorganic chemicals" group grew strongly between 1972 and 1979 (6.4 percent annually), but their output trend reversed subsequently, with the 1979–86 span witnessing a 1.8-percent annual drop. The findings are summarized in the following tabulation:

	Average annual rates (percent) 1972–86	1972–79	1979–86
Inorganic chemicals	−0.1	2.0	−0.3
Alkalies and chlorine ..	−2.7	−6.0	7.9
Inorganic pigments	−2.0	−4.2	1.0
Other basic and miscellaneous inorganic chemicals	1.4	6.4	−1.8

The break in the industry's output trend in 1979 parallels a break in the output measures for some major selected industries which are users of inorganic chemicals, and for which the BLS calculates the measures.[8] For example, output of steel, a large-scale user of such industrial gases as oxygen, and which had been stable during the earlier (1972–79) period, declined by 6 percent annually over the later one (1979–85). Soap and detergent production, an important outlet for phosphates, having risen at close to 2.0 percent per year earlier, receded by 1.6 percent later. (Phosphates in detergents were banned in some States during the survey period, which together with a shift to liquid detergents also reduced phosphate consumption.)[9] Glass containers, primary aluminum, and organic chemicals, all heavy users of certain bulk inorganics, showed the same pattern of expanding, then contracting output rates over the survey period. Following a similar break in the output rate for agricultural crops—from an average annual rate of 3.5 percent for 1972–79 to 0.0 percent for 1979–85—production of the intermediates providing feedstocks for fertilizers dropped from 4.9 percent a year to −0.8 percent.

Table 1. Productivity and related indexes for industrial inorganic chemicals, 1972–86
[1977=100]

Year	Ouput per employee hour: All employees	Production workers	Nonproduction workers	Output	Employee hours: All employees	Production workers	Nonproduction workers
1972 ...	97.3	94.7	103.5	90.6	93.1	95.7	87.5
1973 ...	102.1	97.3	113.8	96.5	94.5	99.2	84.8
1974 ...	104.1	101.2	110.7	105.1	101.0	103.9	94.9
1975 ...	86.5	88.3	82.8	87.0	100.6	98.5	105.1
1976 ...	94.4	96.9	89.7	95.0	100.6	98.0	105.9
1977 ...	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978 ...	102.6	102.9	101.9	105.6	102.9	102.6	103.6
1979 ...	112.2	112.3	112.1	108.5	96.7	96.8	96.8
1980 ...	94.3	98.0	87.4	95.9	101.7	97.9	109.7
1981 ...	91.4	96.0	82.8	93.7	102.5	97.6	113.1
1982 ...	86.3	91.8	76.6	82.7	95.8	90.1	107.9
1983 ...	94.2	101.0	82.4	87.8	93.2	86.9	106.5
1984 ...	106.0	113.5	93.1	98.4	92.8	86.7	105.7
1985 ...	102.6	111.0	88.2	97.5	95.0	87.8	110.5
1986 ...	109.1	117.2	95.4	100.3	91.9	85.6	105.1
	Average annual rates of change (percent)						
1972–86	0.3	1.1	−1.4	−0.1	−0.3	−1.2	1.4
1980–86	4.4	4.9	3.6	2.7	−1.6	−2.1	−0.9

Table 2. Productivity and related indexes for alkalies and chlorine, 1972–86
[1977=100]

Year	Ouput per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972 ...	102.1	96.7	117.6	114.2	111.8	118.1	97.1
1973 ...	102.0	95.4	121.5	116.3	114.0	121.9	95.7
1974 ...	113.3	107.4	129.8	133.6	117.9	124.4	102.9
1975 ...	90.0	87.8	95.4	109.2	121.4	124.4	114.5
1976 ...	98.0	100.2	93.2	112.1	114.4	111.9	120.3
1977 ...	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978 ...	106.6	105.7	108.5	99.1	93.0	93.8	91.3
1979 ...	107.3	109.3	104.8	68.3	63.3	62.5	65.2
1980 ...	115.4	119.9	105.8	67.5	58.5	56.3	63.8
1981 ...	95.3	97.9	89.9	61.2	64.2	62.5	68.1
1982 ...	100.8	104.2	93.7	63.8	63.3	61.2	68.1
1983 ...	127.1	129.6	121.6	79.3	62.4	61.2	65.2
1984 ...	146.3	142.7	155.2	94.5	64.6	66.2	60.9
1985 ...	147.4	146.1	150.2	102.3	69.4	70.0	68.1
1986 ...	179.9	182.2	174.7	101.3	56.3	55.6	58.0
	Average annual rates of change (percent)						
1972–86	3.2	3.7	2.1	-2.7	-5.7	-6.2	-4.7
1980–86	13.6	12.8	15.3	12.5	-1.0	-0.3	-2.5

Employment

Workers employed in the inorganic chemicals industry (excluding Federal Government plants) numbered about 73,000 in 1986, 3 percent below the 1972 level, and 11 percent lower than in 1980, the last peak employment year. Employment tended to decline at an average annual rate of 0.3 percent over the study period, but all of the decline occurred over the 1979–86 span (at a 1.2-percent annual rate). Employee-hours evidenced rate-of-change patterns closely akin to employment.

The proportion of production workers in the industry fell from 68 percent of total employment in 1972 to 62 percent in 1982.[10] In 1986, the number of production workers ran 13 percent below the 1972 count, and 17 percent below its 1980 peak. By contrast, nonproduction worker employment, which had expanded by 20 percent between 1972 and 1986, barely retreated only 7 percent from its earlier peak. The high proportion of nonproduction workers in the industry has resulted from higher-than-average proportions of jobs in managerial and management-related positions, and in engineering and technician occupations. According to BLS data, these three categories accounted for 24 percent of the industry's total employment in 1984, compared to 15 percent for manufacturing as a whole.

Blue-collar occupations in the industry appear to be more highly skilled than in manufacturing generally. In 1984, 30 percent of the employees in inorganic chemicals worked as blue-collar supervisors, construction trades workers, mechanics, installers and repairers, precision production workers, and in plant and systems occupations. The comparable proportion for manufacturing was 20 percent. Twenty percent of all employees worked in less skilled occupations—chemical equipment controllers, operators and tenders, welders, and helpers and laborers; the corresponding figure for manufacturing was 43 percent.[11]

Average hourly earnings in the industry rose faster than the manufacturing average—running 20 percent above the average in 1972, and 34 percent in 1985. During the survey period, female employees' share of employment doubled, to 18 percent; in manufacturing, their employment share rose from 29 to 32 percent. Accession and separation rates per 100 workers, available only through 1981, indicate a fair degree of stability in the stability of the industry's work force. The rates were only about two-fifths as high as for total manufacturing, and point to the industry's ability to retain experienced workers. (Quits per 100 workers ran to only one-third of the manufacturing average.) Overtime schedules in the industry ranged within considerably narrower bounds than in all manufacturing, probably reflecting in part the continuous-process nature of production schedules.[12]

Capital investment

The fixed capital assets of the inorganic chemicals industry are high in relation to employment. As noted earlier, in 1982, the value of assets per employee ran four times higher than the comparable figure for manufacturing generally.[13] In the "other and miscellaneous inorganic chemicals" group, the ratio was three times higher. However, the ratio for the industry as a whole as well as for its component industries had declined from 1972, when it had run 4 to 5 times the manufacturing average. The decline possibly reflected the considerably greater reduction in new capital expenditures by the industry than by manufacturers generally after 1977.

Table 3. Productivity and related indexes for industrial pigments, 1972–86
[1977=100]

Year	Ouput per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972 ...	113.2	108.7	124.8	121.3	107.2	111.6	97.2
1973 ...	114.6	106.0	140.4	130.6	114.0	123.2	93.0
1974 ...	115.4	110.3	129.2	154.7	134.0	140.2	119.7
1975 ...	104.2	105.5	101.6	108.7	104.3	103.0	107.0
1976 ...	100.9	102.2	98.0	109.1	108.1	106.7	111.3
1977 ...	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978 ...	104.8	104.1	106.6	106.6	101.7	102.4	100.0
1979 ...	105.0	104.4	106.5	100.5	95.7	96.3	94.4
1980 ...	102.2	108.6	89.9	101.3	99.1	93.3	112.7
1981 ...	105.1	113.0	90.4	101.9	97.0	90.2	112.7
1982 ...	96.7	108.0	77.7	87.6	90.6	81.1	112.7
1983 ...	104.0	113.8	86.9	93.0	89.4	81.7	107.0
1984 ...	125.7	134.8	108.7	97.9	77.9	72.6	90.1
1985 ...	132.7	144.3	111.9	105.6	79.6	73.2	94.4
1986 ...	133.5	147.1	110.3	110.3	82.6	75.0	100.0
	Average annual rates of change (percent)						
1972–86	0.9	2.1	-1.7	-2.0	-2.8	-3.9	-0.3
1980–86	6.9	7.0	6.8	2.9	-3.7	-3.8	-3.6

The comparison, derived from constant-dollar data, reads as follows[14]:

	Average annual rates (percent)	
	Inorganic chemicals	*Manufacturing*
1972–85	0.2	2.6
1972–77	16.0	5.1
1977–85	−5.4	0.0

Levels of real capital outlays—which in this industry are overwhelmingly for equipment, rather than for structures—peaked in 1977, then fell precipitously; in 1983, they stood 47 percent below their 1977 high. They recovered thereafter, but in 1985, capital outlays still were less than in 8 of the 13 years reviewed here. As the tabulation shows, the amplitudes of the swings in outlays by far exceeded those for all manufacturing.

The large increase in the industry's real capital expenditures during much of the 1970's was to an extent fueled by relatively high capacity utilization rates; their subsequent retreat was occasioned in large part by contracting utilization. Between 1975 and 1980, the ratio of actual to "preferred" or full capacity utilization averaged 77 percent; between 1981 and 1985, it averaged 65 percent.[15] (The pattern was similar but much less accentuated for manufacturing as a whole.) However, the earlier increases in the industry's real capital outlays have been said also to have arisen from erroneous assumptions about longer term demand growth, leading to overexpansion in productive capacity. According to a Brookings Institution study, "Because of the several year-long planning and construction periods for new chemical plants, large scale state-of-the-art plants, designed to achieve economies of scale and maintain or increase market share, continued to be brought on line even when company officials recognized that demand had fallen. These plants were then operated below capacity and thus very inefficiently, production worker requirements in such plants being almost independent of output levels."[16]

Research and development

The National Science Foundation has categorized the inorganic chemicals industry as technology-intensive on the basis of the high ratio of its R&D to value added.[17] That ratio fluctuated between 2.6 and 3.5 percent annually over the survey period.[18] (The all-manufacturing average ranged from 1.9 to 2.6 percent.)

It is difficult to evaluate the focus of the industry's R&D effort, largely because existing survey data encompass the entire chemical industry, except pharmaceuticals.[19] The data are nonetheless suggestive. According to the survey, the annual number of productivity-enhancing process innovations of "major importance" or representing "significant improvement", doubled between the two periods, 1974–79 and 1980–82. Energy-related process innovations rose 34 percent between the two periods. Environment-related process innovations, whose number was lower than those for the two other innovation categories combined, increased by 14 percent. It is noteworthy that when compared with 1967–73, for which the survey also features data, figures for the 1974–79 span represent declines while the 1980–82 period witnessed a recovery in the average annual data (even though the *levels* remained well below 1967–73).

The innovations were linked to new chemical products, whose annual number rose substantially between 1974–79 and 1980–82; and they were embodied in new equipment and instrumentation. The annual number of pertinent innovations nearly doubled for the former, and tripled for the latter.[20] That these improvements occurred in the face of lagging demand for industrial chemicals may be partially ascribed to such factors as the large component of scientists and engineers employed in industrial chemicals, whose efforts focus on problem-solving, including problems generated by the imbalances brought about by the new product and process innovations.[21] The intensity of R&D may also be gauged by the annual rate of chemistry articles published in scientific and technical periodicals, which rose 21 percent between the two periods, 1973–80 and 1981–82;[22] the rise in the so-called citation ratios for these articles;[23] and by the high proportion of articles published in the chemical engineering field (the United States accounted for 50 percent of the world's total, although U.S. employment in the chemical industry represents but one-third of the total of major chemicals-producing countries outside the Soviet bloc).[24] However, the number of patents granted by the United States to resident inventors in the area of inorganic and organic chemistry dropped 19 percent between 1975 and 1981 (yet the number of patents in this area granted to foreign inventors dropped by nearly one-half).[25]

Table 4. Productivity and related indexes for industrial inorganic chemicals, not elsewhere classified, 1972–86
[1977=100]

Year	Ouput per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972 . . .	92.9	89.2	101.9	74.9	80.6	84.0	73.5
1973 . . .	90.5	96.1	104.0	80.7	81.9	84.0	77.6
1974 . . .	102.1	100.2	106.1	88.8	87.0	88.6	83.7
1975 . . .	84.0	86.7	78.9	77.6	94.4	89.5	98.4
1976 . . .	93.9	97.0	87.8	88.7	94.5	91.4	101.0
1977 . . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978 . . .	101.4	101.9	100.4	106.8	105.3	104.8	106.4
1979 . . .	114.6	114.7	114.5	120.3	105.0	104.9	105.1
1980 . . .	90.3	93.8	83.7	101.1	112.0	107.8	120.8
1981 . . .	89.3	93.8	81.2	99.1	111.0	105.7	122.0
1982 . . .	80.8	85.7	72.1	83.6	103.5	97.5	116.0
1983 . . .	86.9	93.0	76.4	87.2	100.4	93.8	114.1
1984 . . .	97.5	105.5	84.3	98.3	100.8	93.2	116.6
1985 . . .	95.3	104.0	81.3	96.3	101.0	92.6	118.5
1986 . . .	101.4	107.1	91.6	100.1	98.7	93.5	109.3
	Average annual rates of change (percent)						
1972–86	−0.2	.6	−1.7	1.4	1.5	0.8	3.1
1980–86	3.6	4.0	3.1	1.7	−1.9	−2.2	−1.3

Exhibit 1. Selected inorganic chemicals and their chief end uses

Chemical	End use	Chemical	End use
Aluminum oxide	Abrasives Refractories Ceramics Electrical insulators Fluxes Spark plugs	Lime	Pollution control Stack gas scrubbers Sewage treatment Acid neutralizer Water treatment
Aluminum sulfate	Pulp and papermaking Treatment of water	Phosphates (in sodium compound)	Insecticidal chemicals Scouring soaps and powders water softeners
Ammonia, anhydrous	Fertilizers Refrigerant Fuel cells and rocket fuel Synethetic fibers Explosives Chemical intermediate	Phosphoric acid	Fertilizers Soap and detergents Rust-proofing
Calcium chloride	Dust control Highway deicing Industrial processing Concrete treatment	Phosphorus	Detergents Beverages Food additives
Calcium phosphate	Animal feed supplements Food supplements Dough conditioner Fertilizers Dyeing of textiles	Potash	Fertilizers
Caustic soda	Acid neutralizer Pulp and paper making Petroleum refining Soaps and detergents	Silicates	Impregnation of wood and porous metals Oil reclamation Synethetic detergents Textile processing Water treatment
Chlorine	Chemical intermediate Water purification Food processing	Soda ash	Glassmaking Pulp and papermaking Water and sewage
Hydrochloric acid	Activation of petroleum wells Boiler scale removal Pickling and metal cleaning Acidizing Ore reduction	Sulfuric acid	Fertilizers Petroleum refining Pigments Iron and steel pickling
		Titanium oxide	Surface coatings Plastics Paper coatings and fillings

SOURCES: *The Condensed Chemical Dictionary*, 10th ed. (New York, Van Nostrand-Reinhold Co., 1981); *Chemical Origins and Markets*, 5th ed. Stanford Research Institute, 1977; and Bureau of Labor Statistics.

Technological advances

Technological advancement in the inorganic chemicals industry has to an extent been identified with increases in the scale of operations. Scale enlargement reduces capital costs as well as labor and utility costs per unit of output. Quintupling of sulfuric acid production, for example, by simply increasing the size of pressure vessels, pipes, storage tanks, and so forth, can reduce operating costs by 33 percent.[26]

Although effluent problems intensified during the 1970's, and costs of losing business from breakdowns or other interruptions are said to have become less tolerable,[27] there is evidence, in addition to the capital spending boosts already noted for the 1970's, that the scale of operations of chemical plants increased then. Between 1972 and 1982, the number of plants with 1,000 employees or more in the "other basic and miscellaneous inorganic chemicals" group rose 27 percent, and the proportion of employment in the group that these plants accounted for rose from 41 to 48 percent. (The number of small establishments nearly doubled in 1982, accounting for 80 percent of all establishments in the industry. But their share of employment, 14 percent that year, had barely changed from 13 percent a decade earlier.) Furthermore, the average number of employees per large plant rose by 19 percent, to 2,821 in 1982, indicating that existing large plants added to their employment as they expanded their scale of production.[28]

The industry also modernized existing facilities by retrofitting with updated, largely computerized equipment and instrumentation.[29] Computers, programmable controls, computerized sensors for temperature, pressure, flow rate, liquid levels, materials analyzers, and other process variables have been increasingly diffused. Pneumatic controls have been more and more replaced by electronic signals and their apparatus (except in the processing of flammable materials). Reasons for installing computers in chemical processing are succinctly stated in the following passage:

> Sensitive reactions, novel equipment arrangements, or usually complex control schemes represent systems so complex that it is essentially impossible for the human mind to conceive or calculate the process behavior during startup or after disturbance away from steady state. The ease with which the computer can be programed by the engineer, its speed and accuracy in solving differential equations, and the insight it pro-

vides as to the nature of process behavior are three main reasons for the success of the analog computer in the processing industries.[30]

In the mid-1970's, chemical process firms began to use minicomputers and placed less emphasis on mainframe computers.[31] Prices of computers continued to decline. Microprocessors for "small" control problems and for batch sequencing spread through processing installations. Pertinent software and laboratory management systems became more widely available. Computers in laboratories—a working part of all the larger processing facilities—not only aided in making experiments but also suggested them (for example, in modeling molecular constellations). Also, so-called audit trails have been greatly facilitated by computers, making it possible to trace efficiently, and to record, when, how, and by whom test samples were drawn, thus helping to satisfy government and company regulations.[32]

Computers have also become indispensable in chemical engineering. They enable the prediction of the properties of chemicals with new molecular structures. They are vital in designing process equipment. They permit the simulation of process control. And they help in managing resources.[33] Large amounts of engineering time are thus economized. Some complex problems which reportedly required up to 500 hours for their solution can now be tackled in less than half an hour.[34]

Gradual improvements in older technologies relating to established engineering practices have of course also continued. One such practice is "de-bottlenecking." The retrofitting of existing plants with updated equipment and instruments, noted already, often creates imbalances or bottlenecks in chemical processing. Hence, the importance of "de-bottlenecking" appears to have increased over the review period.[35] One technique of coping with bottlenecks has been to install better pumps and valves. That usually spells improved flow, less corrosion, thus also reducing maintenance labor. Among higher speed pumps innovated during the 1970's have been drum pumps that would empty 55-gallon drums within 2 minutes.[36]

Relatively few important innovations or technological changes occurred during the survey period that were specific to the products manufactured by the industry, while at the same time significantly reducing labor requirements per unit of output. Here, two developments may be cited in the chlor-alkali segment of the industry, which probably contributed to this segment's productivity improvement between 1972 and 1985. (See table 2). One was the replacement of older plants operating at an electrical capacity of 20,000 to 50,000 amperes, with plants capable of 100,000 amperes. (Chlorine is produced by electrolysis, usually of sodium chloride brine.) The increase in electrolytical capacity barely changed in unit labor requirements.[37] The other development was a switch in production technology from (electrolytical) mercury cells—entailing the risk of escaping mercury polluting streams—to one based on diaphragms and, subsequently, membranes. The switch saved between 20 and 35 percent in electrical (electrolytical) energy.[38]

A shift from synthetically produced soda ash to natural soda ash mined in open pits (mostly in Wyoming and California) and treated by the so-called Trona process was hastened during the 1970's. This stepped-up activity solved the problem of disposing of the calcium chloride generated by the Solvay process of manufacturing soda ash, and the brine that process generates which would be discharged into—and pollute—streams. Labor requirements per unit of output are lower with Trona mining than with the Solvay process (transport costs may partially offset the savings).[39]

Outlook

It is likely that, beyond cyclical swings, there will be improvement in the productivity of the inorganic chemicals industry over the long term. Such long-term gains may well be associated with continued small overall increases in output being accompanied by still smaller increases—or losses—in employment. Among technological or organizational factors likely to spur productivity are more centralized technical controls of plant complexes, facilitated by comparatively low-cost computer networks. Also probable is the more closely and efficiently scheduled use of processing equipment, and the growing versatility in the processing of cognate chemical products of which such equipment would be capable.[40]

Following steep cuts in the productive capacity of such basic chemicals as sulfuric acid—estimated by some observers to one-third of 1981 levels,[41] and as much as 25 percent of that of phosphoric acid[42]—older equipment has evidently been rapidly phased out in recent years, and it seems probable that such phasing-out will continue for some time. This alone would gradually improve capacity utilization rates, and therefore labor productivity, as more up-to-date processing equipment and instrumentation supplant obsolescent facilities.

The question of whether pollution abatement technology can be increasingly adapted to enhance the efficiency of chemical processing technologies—or whether it will continue to be embodied in the pollution abatement efforts and services of the industry (many of which, however, are conducted outside the industry proper although it bears the costs)—cannot be assayed here. Only a relatively small portion of the industry's pollution abatement costs appear to have been recaptured by merging processing and abatement technologies. It remains, however, that "Every major chemical company has a formidable array of environmental engineers committed to (a) retrofitting existing facilities to meet pollution abatement requirements; and (b) designing new facilities that incorporate the most cost-effective pollution control equipment, usually in anticipation of future requirements."[43]

According to BLS projections, employment in the inorganic chemicals industry will rise 6 percent between 1984 and 1995 if it follows a "moderate" (rather than a "low" or "high") path. Among the industry's major occupational groups, those of engineers, chemists, and engineering and science technicians are anticipated to expand more rapidly than other groups. Although these three groups together accounted for but 14 percent of the industry's total employment in 1984, their share of employment growth will be 37 percent. Likewise, the growth and share of managerial and management related occupations will be roughly twice their 1984 employment proportion of 12 percent. Much slower increases are expected for blue-collar jobs. These jobs accounted for almost one-half of total industry employment in 1984, but will make up little more than two-fifths of employment growth by 1995. Large job losses are projected to occur in administrative support occupations, particularly among clerical personnel.[44] □

——FOOTNOTES——

[1] Industrial inorganic chemicals are classified as No. 281 in the *Standard Industrial Classification Manual* of the Office of Management and Budget. SIC 281 is composed of four 4-digit industries—SIC 2812, Alkalies and Chlorine, consisting of establishments manufacturing these two chemicals and such other related chemicals as soda ash and caustic soda; SIC 2813, Industrial Gases, with establishments manufacturing such gases as acetylene, carbon dioxide, oxygen, and others; SIC 2816, Inorganic Pigments, with establishments manufacturing pigments destined mostly for industrial paints, such as used for automobiles and household appliances; and SIC 2819, Industrial Inorganic Chemicals, not elsewhere classified, with establishments manufacturing a wide variety of bulk or commodity chemicals, such as acids, phosphates, potassiums, sulfurs, sodiums (salts), metallic compounds, and catalysts.

SIC 2819 includes government-owned establishments; the output and employment of this part of the industry are excluded from the productivity and related measures offered here. The productivity and related measures for SIC 2813, Industrial Gases, are not published separately but are included in the measured for SIC 281.

Average annual rates of change presented in this article are based on linear least squares of the logarithms of the index numbers. The indexes will be updated annually and will appear in the annual BLS Bulletin, *Productivity Measures for Selected Industries.*

[2] R. Norris Shreve and Jospeh A. Brink, Jr., *Chemical Process Industries* (New York, McGraw-Hill Book Co., 1977), ch. 1.

[3] Martin Neil Baily and Alok K. Chakrabarti. "Innovation and Productivity in U.S. Industry," *Brookings Papers on Economic Activity*, 2:1985, p. 624.

[4] Bureau of the Census data. The data for government-owned establishments are excluded here.

[5] Baily and Chakrabarti write that excess capacity in the industry "brings about a substantial drop in productivity performance," p. 615.

[6] *The Condensed Chemical Dictionary* (New York, Van Nostrand-Reinhold Co. 1981).

[7] U.S. Department of Commerce, Bureau of Economic Analysis, *The Detailed Input-Output Structure of the U.S. Economy*, 1977, Vol. I (Washington, U.S. Government Printing Office, 1984).

[8] Output of selected industries using inorganic chemicals on a large scale are shown below:

	Average annual rates of change (percent)		
	1972–85	1972–79	1979–85
Steel	−3.3	0.0	−6.1
Paints and allied products	.7	1.9	.4
Paper, paperboard, and pulp	1.8	1.7	1.8
Soap and detergents	1.2	1.8	−1.1
Miscellaneous plastics	5.7	6.6	6.2
Glass containers	−1.1	1.1	−3.2
Primary nonferrous metals	−4.2	−2.7	−6.2
Primary aluminum	−.3	2.5	−4.7
Aluminum rolling and drawing	.9	2.6	.1
Agricultural chemicals	3.5	4.9	−.8
Prepared feeds	2.6	2.4	2.5
Motor vehicles	1.4	4.4	5.2
Organic chemicals	1.8	5.8	−2.1
Petroleum refining	.0	−3.2	−2.2

[9] *Chemical and Engineering News*, Jan. 26, 1987.

[10] Refers to production workers in the industry's privately owned establishment as do all other employment as well as output and productivity data in this article.

[11] The high skill composition of labor in the industry is emphasized in the following:

"The conduct of chemical plants requires, as a rule, skilled labor, with a limited requirement for ordinary backbreaking work. Most of the help needed is for workers who can repair, maintain, and control the various pieces of equipment and instruments necessary to carry out chemical conversions and physical operations. ...(The) chemical industry, by virtue of a wider use of instruments and a greater complexity of equipment, requires more and more skilled labor," *Chemical Process Industries*, p. 20.

[12] Following are overtime hours in industrial inorganic chemicals and manufacturing, 1972–85.

Year	*Industrial inorganic chemicals*	*Manufacturing*
1972	94	95
1973	106	103
1974	111	89
1975	86	70
1976	103	84
1977	100	100
1978	94	103
1979	97	95
1980	86	76
1981	91	76
1982	86	59
1983	83	81
1984	94	92
1985	94	89

[13] Data and discussion exlude government-owned establishments.

[14] Deflator from table B-3, *Economic Report of the President*, January 1987 (implicit price deflator, total nonresidential gross private domestic investment).

[15] U.S. Department of Commerce, Bureau of the Census, *Survey of Plant Capacity*, 1985 and earlier years.

[16] Baily and Chakrabarti, p. 624.

[17] National Science Board, *Science Indicators - The 1985 Report* (Washington, U.S. Gopvernment Printing Office, 1985), p. 197.

[18] National Science Foundation, *Research and Development in Industry*, 1984 (Washington, U.S. Government Printing Office, 1985), p. 34.

[19] However, "other" chemical industries, including SIC 284,5 and 287–9 are much less research-intensive than industrial chemicals. See footnote 18.

[20] Baily and Chakrabarti, p. 616.

[21] See Richard C. Levin, "Technical Change and Optimal Scale: Some Evidence and Implications," *Southern Economic Journal*, October 1977,

p. 208. The author also writes: "The technology itself generates concrete identifiable problems upon which engineers and applied scientists focus their innovative efforts" (p. 219). Also: "Efforts to reduce machine 'downtime' focus upon design considerations to hasten servicing when necessary, and to lengthen the intervals between servicing.

[22] *Science Indicators*, p. 193.

[23] *Science Indicators*, p. 195.

[24] *Eurostat, Employment and Unemployment: Yearbook of Labor Statistics, 1982.* (Tokyo, Japan, Ministry of Labor, 1985).

[25] *Science Indicators*, p. 25.

[26] Levin, p. 213.

[27] *Chemical and Engineering News*, Mar. 6, 1978, p. 24.

[28] The data do not indicate enlargement of scale of government-owned establishments in the industry.

[29] *Chemical and Engineering News*, Dec. 7, 1981. p. 15ff.

[30] Quoted in *Chemical Process Industries*, p. 12.

[31] *Chemical Engineering News*, Sept. 16, 1974, p. 52ff.

[32] *Chemical Engineering News*, Aug. 19, 1985, p. 21ff.

[33] *Chemical Engineering News*, Oct. 1, 1983, p. 31.

[34] *Chemical Engineering News*, Aug. 12, 1985, p. 7ff.

[35] Industry information and *Chemical Engineering News*, May 14, 1987.

[36] *Chemical Engineering*, Apr. 1, 1985, p. 14.

[37] Industry information.

[38] *Chemical and Engineering News*, Mar. 20, 1978, p. 20ff.; February 8, 1982, p. 105; Oct. 29, 1984.

[39] Industry information; *Chemical and Engineering News*, Sept. 8, 1986, p. 17; p. 211.

[40] *Chemical and Engineering News*, Dec. 7, 1981, p. 19.

[41] Industry information.

[42] *Chemical and Engineering News*, Oct. 11, 1982, p. 16.

[43] U.S. Environmental Protection Agency, *Voluntary Environmental Activities of Large Chemical Companies to Assess and Control Industrial Chemicals*, Sept. 1976, p. 7.

[44] See *Occupational Outlook Handbook, 1986–87*, Bulletin 2250 (Bureau of Labor Statistics, 1987), p. 269ff.

APPENDIX: Measurement techniques and limitations

Indexes of output per employee hour measure changes in the relation between the output of an industry and the employee hours expended on that output. An index of output per employee hour is derived by dividing an index of output by an index of industry employee hours.

Real output was calculated in terms of the deflated value of shipments (adjusted for inventory change) for each product group. Changes in prices were removed from the current-dollar values by means of appropriate price indexes at various levels of subaggregation for a variety of products in each group. In order to combine the output segments to a total output index, employee hour weights relating to the individual segments were applied.

Complete output data are available only in years for which a Census of Manufactures is taken (such as 1972, 1977, 1982). For the intercensal years, the data are based on samples, and are not quite so complete. Therefore, these data are benchmarked to census year data.

The indexes of output per employee hour relate total output to one input—labor. The indexes do not measure the specific contribution of labor, capital, or any other single factor. Rather, they reflect the joint effects of factors such as changes in technology, capital investment, capacity utilization, plant design and layout, skill and efforts of the work force, managerial ability, and other factors.